REMARKS

Entry of the present amendment under Rule 116 and reconsideration of the above-identified patent application, as amended, is respectfully requested. The present amendment is responsive to the Office Action mailed March 26, 2003. A petition for an extension of time in which to respond to the Office Action accompanies this amendment.

By the present amendment, claims 4-6 are pending in the application.

Support For Claim Amendment

Support for the amendment to independent claim 4 may be found in the specification, e.g., at page 7, lines 6-9. Support for the upper limit of 0.035% for acid soluble aluminum may be found in Example 2, page 18, line 13. Support for the lower limit of 0.0060 for nitrogen may be found in the specification in Example 3, page 19, line 15.

New matter is not being presented by the present amendment.

§103

Claims 4-6 were rejected under 35 U.S.C. §103(a) as being unpatentable over U.S. Patent No. 5,190,597 to Kobayashi et al. or U.S. Patent No. 4,979,996 to Kobayashi et al. in view of U.S. Patent No. 4,054,471 to Datta, U.S. Patent No. 3,969,162 to Henke or U.S. Patent No. 4,318,758 to Kuroki et al. and further teaching of U.S. Patent No. 4,595,426 to Iwayama et al.

These rejections, as applied to the amended claims, are respectfully traversed.

The Present Invention

The present invention is a method for producing a thick grain-oriented electrical steel sheet with excellent magnetic properties.

The present invention has the following features.

(a) the slab contains Al as an essential component and AlN as the main inhibitor;

(b) the carbon content in a slab is selected to provide the defined carbon steel in the final product (less than 0.0050% C after decarburization);

(c) it uses a low slab heating temperature, i.e., not higher than 1,300°C,

(d) nitriding treatment;

(e) combining of SF and $\Delta\Theta$ (crystal orientation deviation) values and

(f) the sheet measures 0.36 to 1.00 mm in thickness, which in combination with the other features defined in the claim are important. Features (a) to (d) are closely interrelated with respect to the control of the behavior of inhibitors for the secondary recrystallization.

Sheet Thickness

The thickness of the sheet of the present invention is 0.36 to 1.00 mm.

In the prior art, the trend was to decrease the thickness in order to improve the core loss properties of grain-oriented electrical steel sheet. That is, the sheet thickness was within the range of 0.23 - 0.35 mm.

Laminations of grain-oriented electrical steel sheets are used to make transformers, and using thicker sheet reduces the amount of work needed to make a core of a given size. From transformer manufacturers, there has been a strong demand for ways to reduce the number of lamination steps and improve labor productivity. However, using thicker grain-oriented electrical steel sheet greatly increased the steel producer's manufacturing costs, increasing the price of the steel sheet.

A sheet thickness of 0.35 mm represented a balance between manufacturing ease, including in terms of cost, and the sheet thickness sought by transformer manufacturers. There were commercial products up to that thickness. Mathematically, 0.35 mm and 0.36 mm are close, but in terms of the production of grain-oriented electrical steel sheet, 0.36 mm was the critical point. The difference between sheet product thickness of up to 0.35 mm and 0.36 mm and thicker sheet is considerable in terms of conditions of use by customers. With respect to the number of core layer stacking steps involved in the transformer manufacturing process, 0.40 mm sheet translates into 14% fewer steps compared to 0.35 mm sheet (0.40 mm/0.35 mm - 1), amd 0.50 mm

sheet translates into 43% fewer steps (0.50 mm/0.35 mm - 1).
In the case of a labor-intensive industrial product such as
the manufacture of transformers, this reduction of over 10%
in the number of steps involved in the core stacking process
is extremely worthwhile.

The present invention is thick steel sheet that
meets these needs, a method of producing thick grain-
oriented electrical steel sheet having excellent magnetic
flux density and core loss values.

Nitriding

In accordance with the present invention, the
steel sheet having the final thickness is nitrided following
decarburization annealing.

To form a good primary recrystallization texture
in the production process, it is necessary for the prior art
melt to have a carbon content of 0.040 - 0.085%. In terms
of the end product, this means not more that 0.0050%, so
decarburization is performed in an intermediate step. Since
the ease of the decarburization is inversely proportional to
the square of the sheet thickness, and a tight oxidation
layer is formed during the decarburization, it has been
necessary to subject thicker sheet (ovr 0.35 mm) to two
decarburization passes, between which the sheets have to be
pickled in an acid solution to remove an oxidation layer
causing decarburization-difficulty. This made the

production process very costly, to the extent that, in practice, it was not commercially viable. Since the ease of decarburization is inversely proportional to the square of the thickness, in terms of ease of decarburization, the difference between 0.35 mm and 0.40 mm is not the above 14%, but 31% $((0.40 \text{ mm}/0.35 \text{ mm})^2 - 1)$.

The thickness of the sheet of the subject invention is 0.36 mm to 1.00 mm, so the ease of decarburization decreases compared to thinner sheet less than 0.36 mm thick.

Thus, a nitriding production method, as in the case of the present invention, enables a low slab heating temperature, so the carbon content during melt preparation can be decreased.

Prior Art

The Office Action cited the following United States Patents against the claims.

USP 5,190,597

USP 4,979,996

USP 4,054,471

USP 3,969,162

USP 4,318,758

USP 4,595,426

Lines 24 to 30 of the third column of USP 3,969,162 describes 0.020 - 0.030 inches (0.51 - 0.76 mm), and preferably approximately 0.026 inches (0.66 mm). As can be seen from the table of lines 35 to 45, this is operation

D, and describes the <u>intermediate sheet thickness</u>. The <u>end thickness</u> disclosed by <u>USP 3,969,162</u> is the 0.012 inches (0.30 mm) produced by the cold rolling of operatioin F. Also, this reference uses MnS as an inhibitor, not the AlN inhibitor based on the nitriding treatment of the present invention.

USP 4,054,471 and USP 4,318,758 describe a thickness of ≤ 0.5 mm (0.020 inches). Whereas in the Examples, <u>USP 4,318,758</u> describes a thickness of 0.3 mm, <u>USP 4,054,471</u> does not describe a sheet thickness in the Examples. Furthermore, <u>USP 4,054,471</u> is a B-containing material, unlike the present invention, which does not contain B and uses AlN as the inhibitor. Neither USP 4,054,471 or USP 4,318,758 describe the slab heating temperature or nitriding.

USP 5,190,597 and USP 4,979,996 describe nitriding, but the sheet thickness in each case is 0.30 mm and each describes a thickness of 0.23 mm in the Examples.

USP 4,595,426 describes a thickness of 0.15 mm to 0.23 mm, and does not mention nitriding.

Comparison of the present invention with cited prior art

In the case of the present invention, subjecting the sheet to <u>nitriding</u> treatment following decarburization annealing is an <u>essential</u> element. However, USP 4,054,471, USP 3,969,162, USP 4,318,758 and USP 4,595,426 have no awareness concerning nitriding treatment, so the production

process of the present invention is clearly different from these references.

USP 5,190,597 and USP 4,979,996 are thin materials and show no awareness with respect to controlling the SF and $\Delta\theta$ values. The present invention uses the combination of SF and $\Delta\theta$ (crystal orientation deviation) values to decrease the core loss.

Invention Step

The Office Action takes the position that USP 4,595,426 discloses the SF less than 0.6 would reduce watt loss and the crystal grains have a maximum 4° to 5° difference orientation at the grain boundaries for high-magnetic flux density grain-oriented silicon steel sheets; and that a sheet thickness would affect the watt-loss; and that therefore, from what the reference teaches, it would be obvious to control the SF and grain orientation in order to reduce watt-loss and improve magnetic flux density.

However, USP 4,595,426 relates to the production of thin steel sheets (0.15 to 0.23 mm) and does not disclose the use of nitriding treatment in the production process. The present invention uses nitriding treatment to bring the total N in the sheets to 0.010 to 0.027%, which strengthens the inhibitor. That is, the nitriding treatment controls the inhibitor behavior for obtaining secondary recrystallization grains. Even if the SF and the orientation difference at the grain boundaries are described, the different technology of the production

process of USP 4,595,426 cannot be applied to the production

of thick sheet.   It is therefore submitted that the

position taken by the Office Action is unjustified.

USP 4,054,471 and USP 4,318758 both describe a

sheet thickness of ≤ 0.5 mm. However, USP 4,318,758

describes a thickness of 0.3 mm in the Examples, and USP

4,054,471 does not describe the sheet thickness in the

Examples. This is proof that neither has an actual

awareness about producing the thick steel sheet of the

present invention.

Moreover, since neither USP 4,054,471 or USP

4,318,758 uses nitriding treatment, the production process

is different. Compared to the present invention, with its

different production process, the Office Action is not

justified in maintaining the thicker sheet thickness of the

present invention is conventional.

USP 5,190,597 and USP 4,979,996 use nitriding

treatment but are methods for producing thin steel sheet,

and neither shows any awareness relating to SF and $\Delta\theta$ values.

USP 4,595,426, which is a method of producing thin sheets,

does disclose an SF value and a maximum 4° to 5° difference

orientation at the grain boundaries, but has no disclosure

or suggestion about nitriding treatment used in the thick

sheet process of the present invention. Therefore, while

combining USP 5,190,597, USP 4,979,996 and USP 4,595,426

might facilitate production of thin steel sheet, it would

not enable production of thick sheet.

As previously discussed, U.S. Patent No. 3,969,162 is actually a thin sheet process, and does not use the AlN inhibitor based on the nitriding treatment of the present invention

Summary

In accordance with the present invention, an Al-containing slab is heated at a low temperature and hot-rolled and cold-rolled to obtain steel sheet having a final thickness of 0.36 to 1.00 mm. The steel sheet is subjected to decarburization annealing, followed by nitriding treatment. It is a method for producing thick electrical steel sheet having excellent magnetic flux density and core loss property.

This is the first time the production method of the present invention has been commercially established, so that compared to the prior art, the present invention is a novel and nonobvious method having an inventive step, and is therefore patentable.

It is therefore submitted that amended independent claim 4, and claims 5 and 6 dependent thereon, are patentable over U.S. Patent No. 5,190,597 to Kobayashi et al., U.S. Patent No. 4,979,996 to Kobayashi et al. in view of U.S. Patent No. 4,054,471 to Datta, U.S. Patent No. 3,969,162 to Henke or U.S. Patent No. 4,318,758 to Kuroki et al. and further teaching of U.S. Patent No. 4,595,426 to Iwayama et al.

The following is a marked version of amended claim 4.

--4. (Amended) In a method for producing a thick grain-oriented electrical steel sheet with excellent properties, the method comprising:

preparing a slab comprising, by weight, 0.025 - 0.075% of C, 2.5 - 4.5% of Si, <u>0.025 - 0.035% of acid soluble Al, 0.0060 - 0.0086% of N, 0.070 - 0.161% of Mn, 0.005 - 0.029% of S</u> [optionally one or more inhibitor-forming elements selected from the group consisting of Al, N, Mn, S, Se, Sb, B, Cu, Nb, Cr, Sn, Ti and Bi], and the balance being iron and unavoidable impurities;

heating the slab to a temperature not higher than 1,300°C, hot rolling the slab to a hot-rolled sheet, optionally annealing the hot-rolled sheet,

cold rolling the hot rolled sheet to a cold-rolled sheet by a reduction ratio of not less than 80% by using a one stage cold rolling or two or more stages of cold rolling with intermediate annealing,

decarburization annealing the cold-rolled sheet for decarburization of the sheet at a temperature of 700 - 1,000°C,

treating the cold-rolled sheet for nitriding by using NH_3 gas, and final annealing,

wherein the improvement comprising the sheet has a final thickness of 0.36 - 1.00 mm,

setting C-content to not greater than 0.0050% by weight after decarburization annealing of the sheet,

setting total N-content to 0.010 - 0.027% by weight after nitriding treatment of the sheet in NH_3 gas following said decarburization annealing,

coating the nitrided sheet with an annealing separation agent consisting essentially of MgO and subjecting the coated sheet to final annealing as a coil having a coil inside diameter within a range of 200 - 1500 mm to obtain grains of a selected diameter, its grains of a diameter exceeding 5 mm having a crystal orientation deviation of 0.2 - 4 degrees in relation to that at the grain center, and a post-final-annealing SF value of less 0.80, where SF is defined as

$$SF = (grain\ area\ x\ 4\pi)/(grain\ boundary\ length)^2,$$

whereby a magnetic flux density B_8 of the sheet is not less than 1.83T and core loss $W_{17/50}$ (w/kg) of the sheet is not more than 3.3 x t + 0.35.--

CONCLUSION

It is submitted that in view of the present amendment and foregoing remarks, the application is now in condition for allowance. It is therefore respectfully requested that the application, as amended, be allowed and passed to issue.

Respectfully submitted,

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